***********************DRAFT*************************

SYNOPSIS V1.0:
Heavy Ion Transient and Latch-up Test Results for the Texas Instruments LM193

Anthony Sanders[1], Jim Howard[2], Robert Reed[1], and Jim Forney[2]

1. NASA/Goddard Space Flight Center, Greenbelt, Maryland 20771
2. Jackson and Tull Chartered Engineers

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I. INTRODUCTION

This study was undertaken to determine the Single Event Transient (SET) and Single Event Latch-up (SEL) sensitivity of the Texas Instruments LM193 Dual Differential Comparator.

II. DEVICES TESTED

Two samples of the Texas Instruments LM193 Dual Differential Comparator were tested. Lot Date Code for the parts tested is 0145.

DUT 1 Package Markings: OACS 0145B 5962-9452601Q94

DUT 2 Package Markings: OACS 0145B 5962-9452601Q95

III. TEST FACILITY

Facility: Texas A&M University Single Event Upset Test Facility.
Flux Range: 7.9×10^2 to 1.15×10^5 particles/cm^2/s.
Particles: Neon, Argon, and Xenon ions were used.

Ion	Energy (MeV)	LET (MeVcm^2/mg)
Ne	285	2.64
Ar	561	8.05
Xe	1722	49.30

IV. TEST METHODS

Temperature: room temperature

Test Hardware: A custom test set was used to supply nominal input levels to the DUTs and monitor the bias supply current for changes resulting from the radiation exposure.

Files were generated for each DUT to track changes in the supply current with a measurement accuracy 100 pA. The current was measured and recorded at 10 ms intervals throughout the exposure. A digital oscilloscope was used to monitor the output of the DUT for transient events during the irradiation.

Software: Customized LABVIEW software provided a user interface to control signals to the DUT. The software also automatically monitored supply currents and generated a file history. The software automatically turned off the DUT power supply when the current exceeded a user-defined value. This predefined current is called the limiting current (I_L). The software also records all transient events to an output file seen by the digital oscilloscope.

Test Techniques: Tests were performed to screen for the possibility of transients and latch-up and measure sensitivity as a function of particle LET for an application specific test setup. Test conditions included the nominal bipolar case level for the Supply Voltage (V_{cc} = ±12 Volts) and maintaining a two volt differential between the input voltages. The V_+ = 1.5,1.8,2.1,2.3, or 2.5Volts with V_- was set to a constant 2 Volts. A fluence of $1x10^7$ ions/cm^2 or less was used at each test condition. The effects observed determined the fluence used. If no transients or latchup events occurred, the fluence was run to at least $1x10^7$ ions/cm^2. If the desired number of transients were observed prior to reaching $1x10^7$ ions/cm^2 the beam was stopped and the fluence recorded. The beam flux range of 7.9 x 10^2 to 1.15 x 10^5 particles/cm^2/s resulted in individual exposures of about between 23 seconds and 9 minutes.

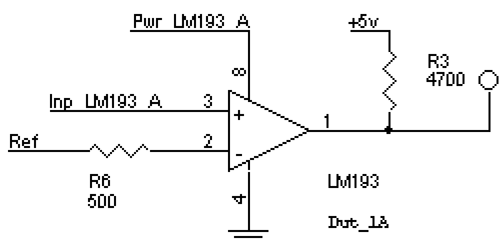


Figure 1. LM193 Differential Comparator configured with a 2-volt reference input to compare for high or low output.

The input voltage condition was evaluated at 3 different normal-incidence values of Linear Energy Transfer (LET). Testing began with a normal incident LET of 2.64 MeV-cm^2/mg obtained with Neon ions, followed with a normal incident LET of 8.05 MeV-cm^2/mg obtained with Argon ions, and finally a normal incident LET of 49.30 MeV-cm^2/mg obtained with Xenon ions. Angles of 0, 45, and 60 degrees were used to achieve 8 different effective LETs (only 0 and 60 degrees were used for the Xenon ions). Two samples were tested under all voltage conditions.

If the device current experienced a sudden increased larger than I_L, the power was cycled and the DUT was checked for functionality, we called this an SEL. The DUT functionality information was not saved to a file. Any transient events observed by the digital oscilloscope were recorded and saved to a file.

V. RESULTS

The devices were exposed from a fluence of 1.68 x 10^5 to 1 x 10^7 particles/cm^2 of the Neon, Argon, and Xenon ions with no single event latchups. The Texas Instruments LM193 is considered to have an LET threshold for latchup greater than 98.6 MeV-cm^2/mg.

The test conditions and results are summarized in Table 1. The table is organized such that the input conditions and angle of incidence are sorted by increasing LET for a low output and then high output. A quick look at the results shows that for an LET of 2.64, no transients were observed with a 1.5V input at 0 degrees.

Table 1. Test Conditions & Results

DUT #	Angle (Degrees)	V_{cc} (Volts)	V_+ (Volts)	V_- (Volts)	Output (Volts)	Effective LET (MeV-cm^2/mg)	Number of Transients	Cross Section (cm^2)
1	0	12	1.5	2	0	2.64	0	1.00E-07
2	57	12	1.5	2	0	4.85	10	1.00E-06
1	60	12	1.5	2	0	5.28	22	2.20E-06
1	0	12	1.5	2	0	8.05	205	1.30E-04
1	60	12	1.5	2	0	16.10	210	4.55E-04
2	60	12	1.5	2	0	16.10	249	5.16E-04
1	0	12	1.5	2	0	49.30	126	1.26E-05
1	60	12	1.5	2	0	98.60	202	1.67E-04
2	60	12	1.5	2	0	98.60	219	8.23E-04
1	0	12	1.8	2	0	2.64	23	2.30E-06
2	0	12	1.8	2	0	2.64	30	3.00E-06
2	57	12	1.8	2	0	4.85	151	1.51E-05
1	60	12	1.8	2	0	5.28	244	4.86E-05
1	0	12	1.8	2	0	8.05	268	4.31E-04
2	0	12	1.8	2	0	8.05	263	3.82E-04
1	60	12	1.8	2	0	16.10	227	5.25E-04
2	60	12	1.8	2	0	16.10	253	6.07E-04
1	0	12	1.8	2	0	49.30	159	1.59E-05
2	0	12	1.8	2	0	49.30	3469	3.47E-04
1	60	12	1.8	2	0	98.60	224	1.56E-04
2	60	12	1.8	2	0	98.60	219	8.02E-04
1	0	12	2.1	2	5	2.64	2	2.00E-07
2	0	12	2.1	2	5	2.64	7	7.00E-07
1	45	12	2.1	2	5	3.73	62	6.21E-06
2	45	12	2.1	2	5	3.73	50	5.00E-06
1	60	12	2.1	2	5	5.28	148	1.48E-05
1	0	12	2.1	2	5	8.05	250	4.20E-04
2	0	12	2.1	2	5	8.05	232	3.48E-04
1	60	12	2.1	2	5	16.10	263	6.26E-04

2	60	12	2.1	2	5	16.10	242	5.78E-04
1	0	12	2.1	2	5	49.30	231	1.15E-03
2	0	12	2.1	2	5	49.30	249	1.00E-03
1	60	12	2.1	2	5	98.60	222	1.32E-03
2	60	12	2.1	2	5	98.60	246	1.46E-03
2	57	12	2.1	2	5	4.85	105	1.05E-05
1	45	12	2.3	2	5	3.73	0	1.00E-07
1	60	12	2.3	2	5	5.28	52	5.20E-06
1	0	12	2.3	2	5	8.05	254	2.89E-04
1	60	12	2.3	2	5	16.10	267	6.69E-04
1	0	12	2.1	2	5	2.64	0	1.00E-07
2	57	12	2.1	2	5	4.85	0	1.00E-07
1	60	12	2.1	2	5	5.28	3	3.00E-07
1	0	12	2.1	2	5	8.05	209	7.33E-05
2	0	12	2.1	2	5	8.05	211	1.07E-04
1	45	12	2.1	2	5	11.38	242	3.81E-04
1	60	12	2.1	2	5	16.10	312	6.24E-04
2	60	12	2.1	2	5	16.10	242	6.11E-04
1	0	12	2.1	2	5	49.30	209	1.10E-03
2	0	12	2.1	2	5	49.30	233	9.51E-04
1	60	12	2.1	2	5	98.60	315	1.01E-03
2	60	12	2.1	2	5	98.60	244	1.23E-03

The cross section curve for single event transients, as shown in Figure 2, is divided into two curves, low and high output conditions. The top curve, for low output conditions, has a threshold for events in this condition of approximately 2 - 5 MeV-cm^2/mg and a saturation cross-section of approximately 1 x 10^{-3} cm^2. At approximately 45 MeV-cm^2/mg and a cross-section of 1 x 10^{-5} cm^2 possible dosimetry errors were observed (the validity of these data points are in question). The bottom curve, for high output conditions, shows similar values for threshold and saturation cross section.

To examine the nature of the transients themselves, Full Width Half Maximum (FWHM) pulse width and each transient's peak voltage scatter plots of are used. Figures 3 and 6 show transient pulse height versus FWHM width for low effective LET of 5.3 and high effective LET of 98 for both low (Figure 3) and high (Figure 6) output cases respectively. These plots show the distribution of pulses expected, as every transient collected for these conditions is plotted as a single data point.

Figures 4 shows sample transients for the low effective LET for the low output case, with the shortest transient occurring at about 3 volts with a FWHM width of less than .5 us. The widest transient occurs at about 5 volts with a FWHM width of less than 1 μs. Similarly, Figure 5 shows sample transients for the high effective LET for the low output case, with the shortest transient occurring at about 1.5 volts with a FWHM width of less than 1 μs. The widest transient occurs at about 5 volts with a FWHM width of less than 1.5 μs. Inversely, these findings are verified with similar results in Figures 7 and 8 for low effective LET, high input case and high effective LET, high input case respectively.

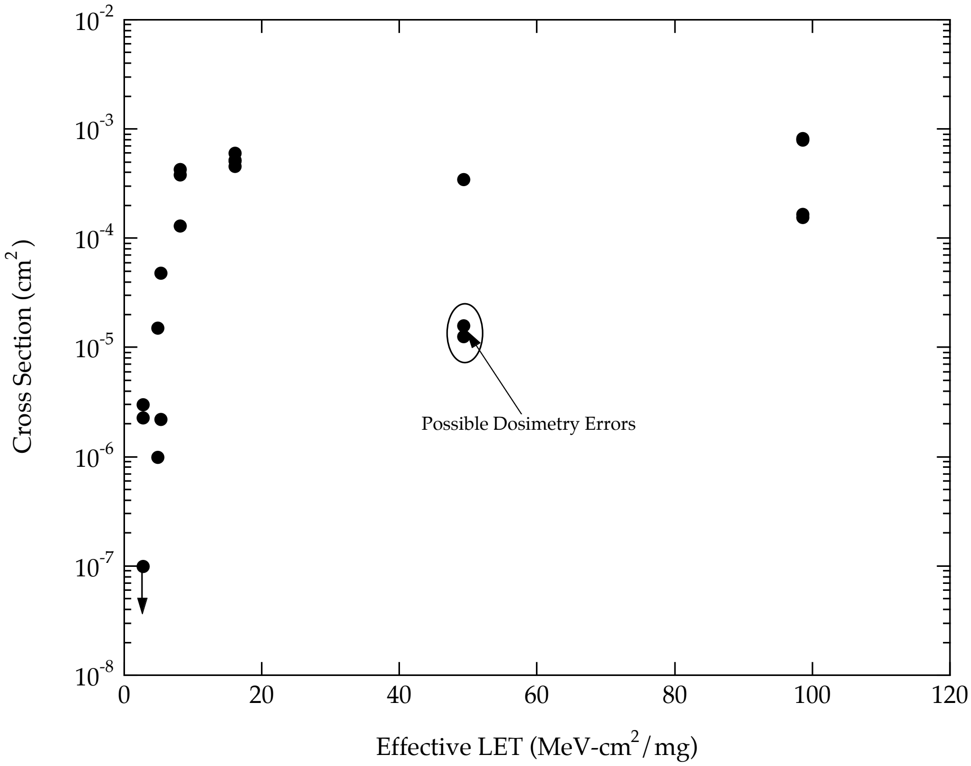
In summary, the Texas Instruments LM193 is considered to have an LET threshold for latchup greater than 98.6 MeV-cm^2/mg. For single event transients, the approximate LET threshold is 2 - 5 MeV-cm^2/mg and the device saturation cross section is 1 x 10^{-3} cm^2. It must be noted that these results are for the application specific test condition as requested by the MLA project and are therefore only applicable to those conditions.

VI. COMMENTS AND RECOMMENDATIONS

In general, devices are categorized based on heavy ion test data into one of the four following categories:

Category 1 Recommended for usage in all NASA/GSFC spaceflight applications.
Category 2 Recommended for usage in NASA/GSFC spaceflight applications, but may require mitigation techniques.
Category 3 Recommended for usage in some NASA/GSFC spaceflight applications but requires extensive mitigation techniques or hard failure recovery mode.
Category 4 Not recommended for usage in any NASA/GSFC spaceflight applications.

The Texas Instruments LM193 Dual Differential Comparators are considered category 2 devices.



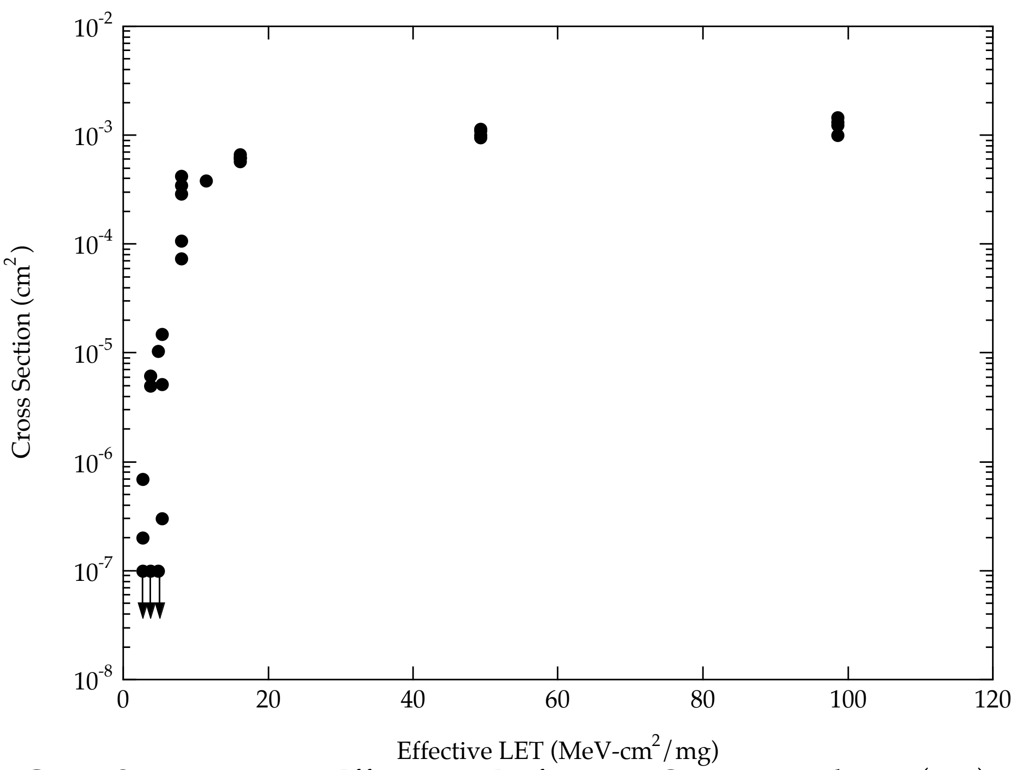


Figure 2. Cross-Section versus Effective LET for Low Output condition (top) and High Output condition (bottom). Data points with a down-pointing arrow indicate that no events were observed under those conditions.

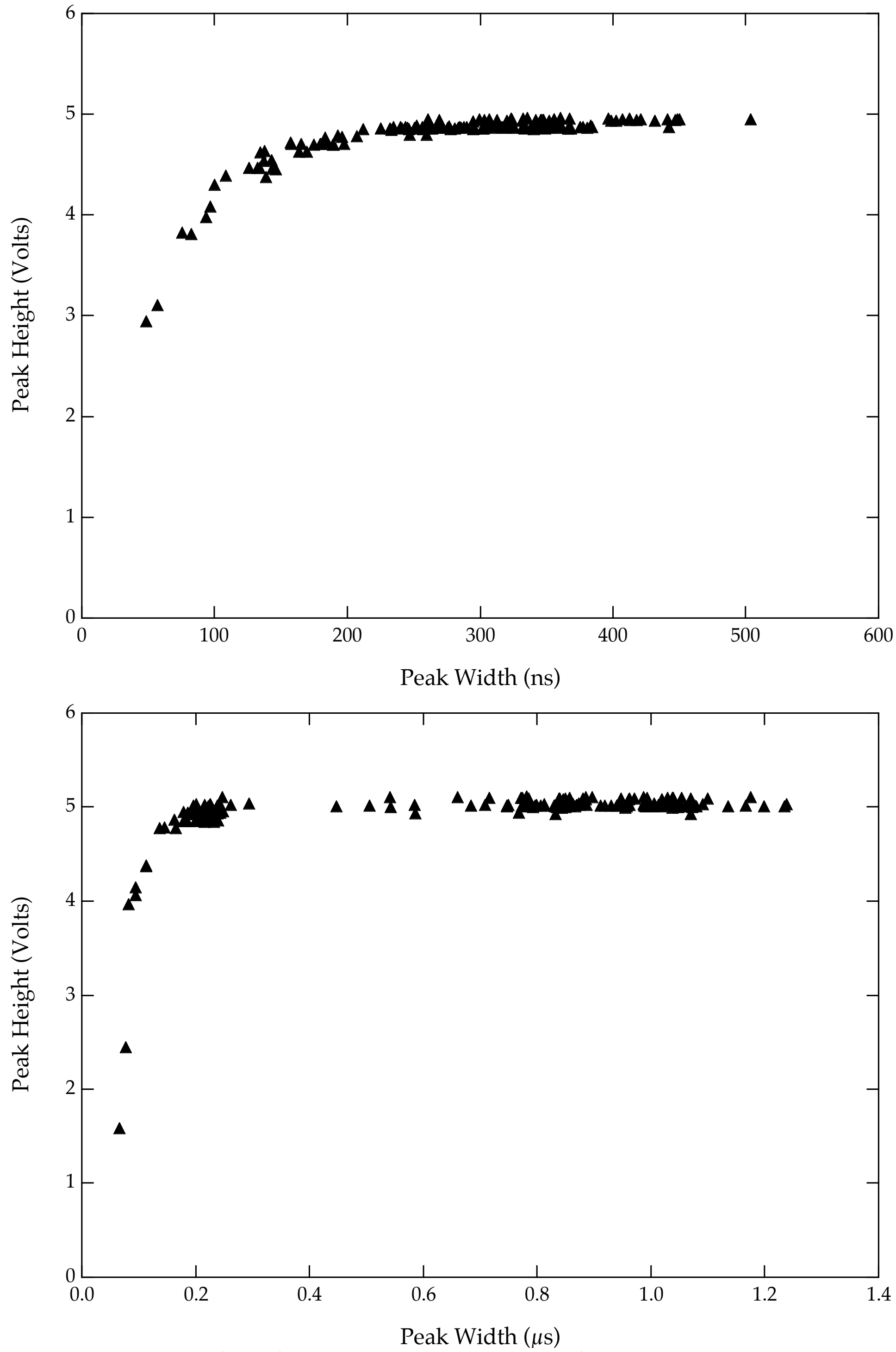
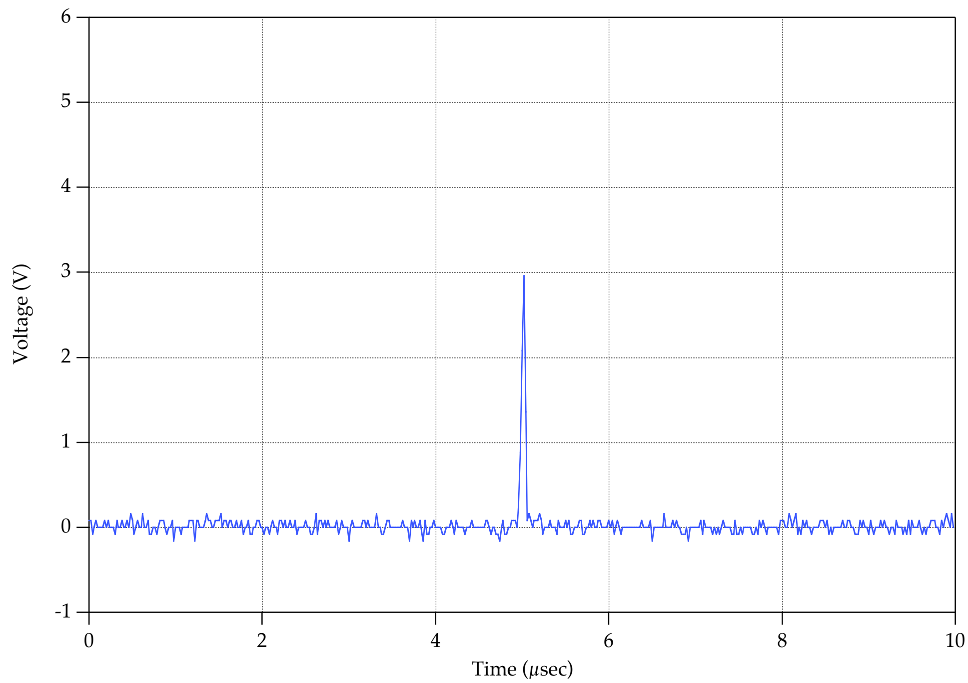


Figure 3. Transient pulse height versus FWHM width for low effective LET = 5.3 (top) and high effective LET = 98 (bottom) for the low output case.



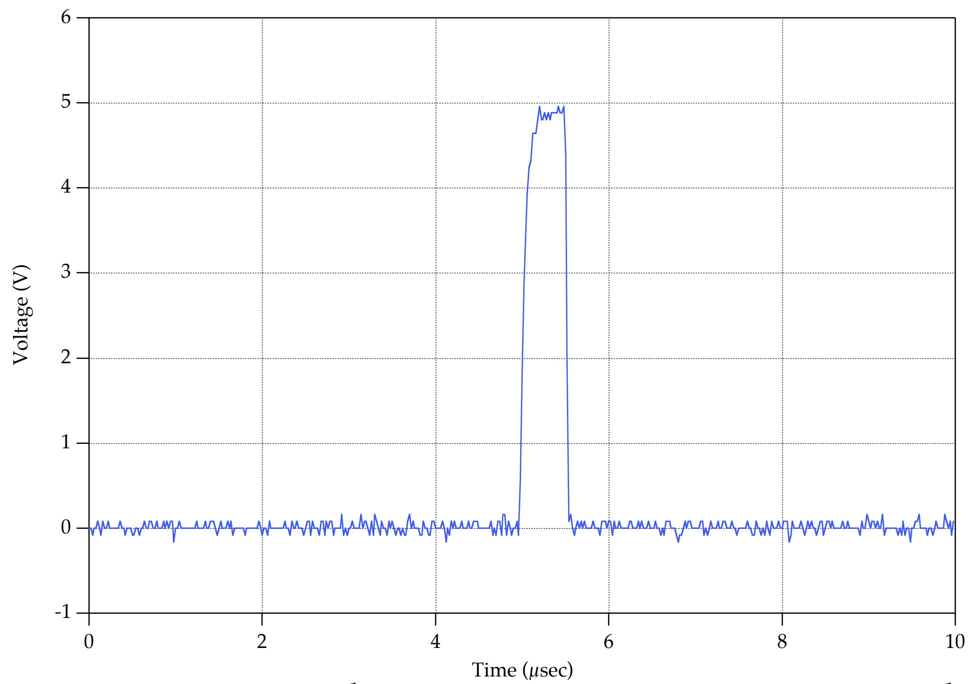


Figure 4. Sample transients for the low effective LET, low output case showing the shortest transient (top) and widest transient (bottom).

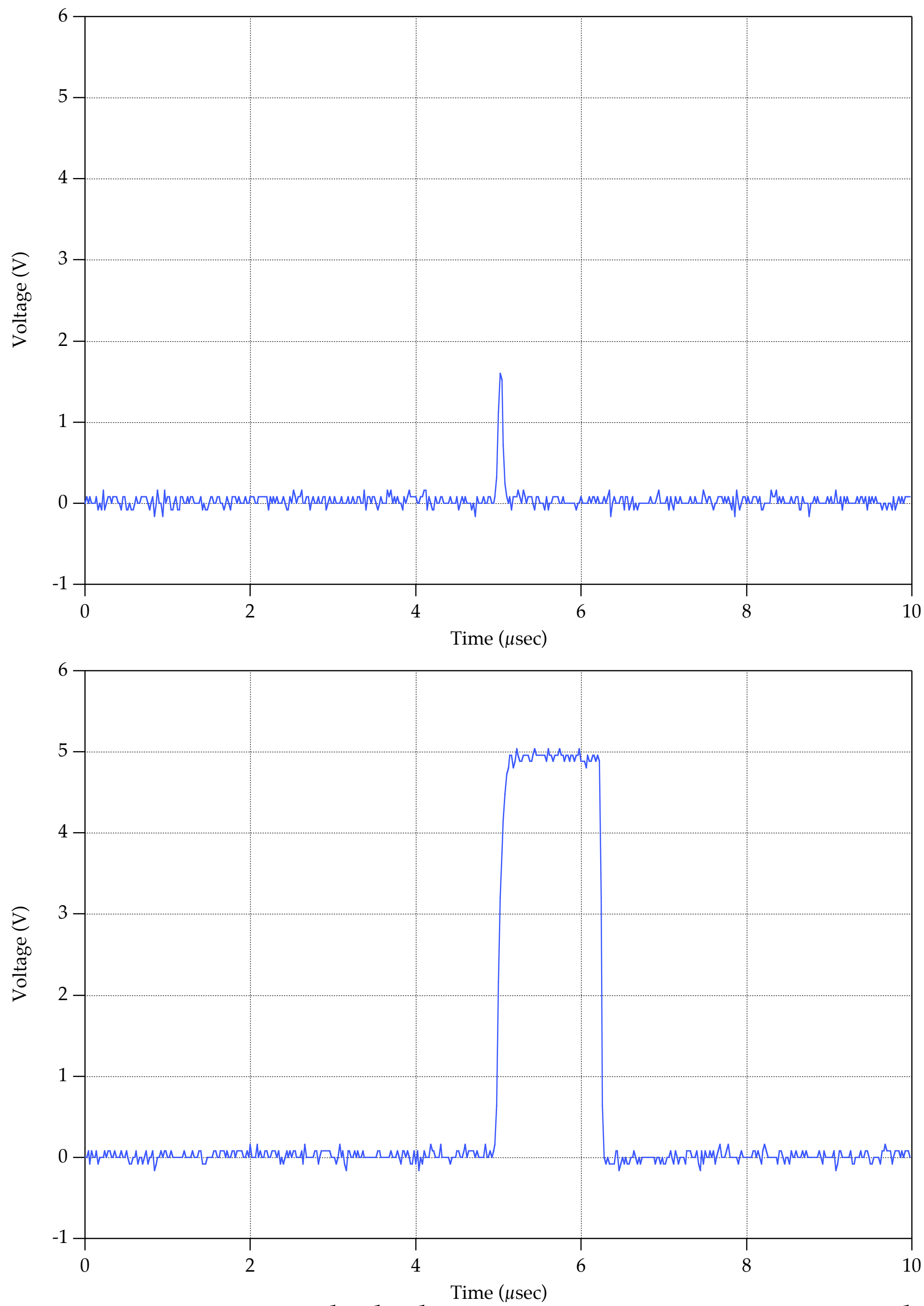


Figure 5. Sample transients for the high effective LET, low output case showing the shortest transient (top) and widest transient (bottom).

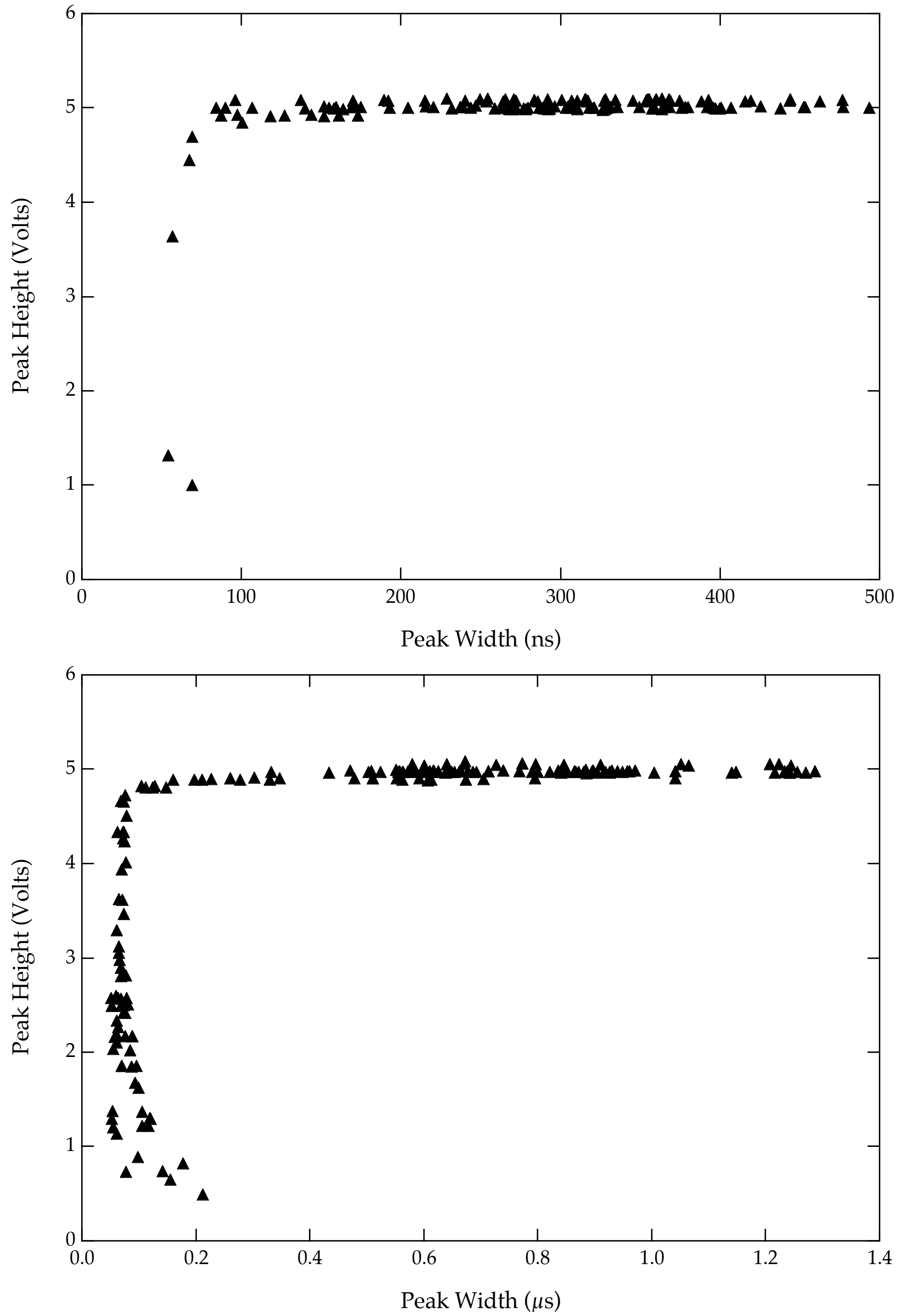


Figure 6. Transient pulse height versus FWHM width for low effective LET = 5.3 (top) and high effective LET = 98 (bottom) for the high output case.

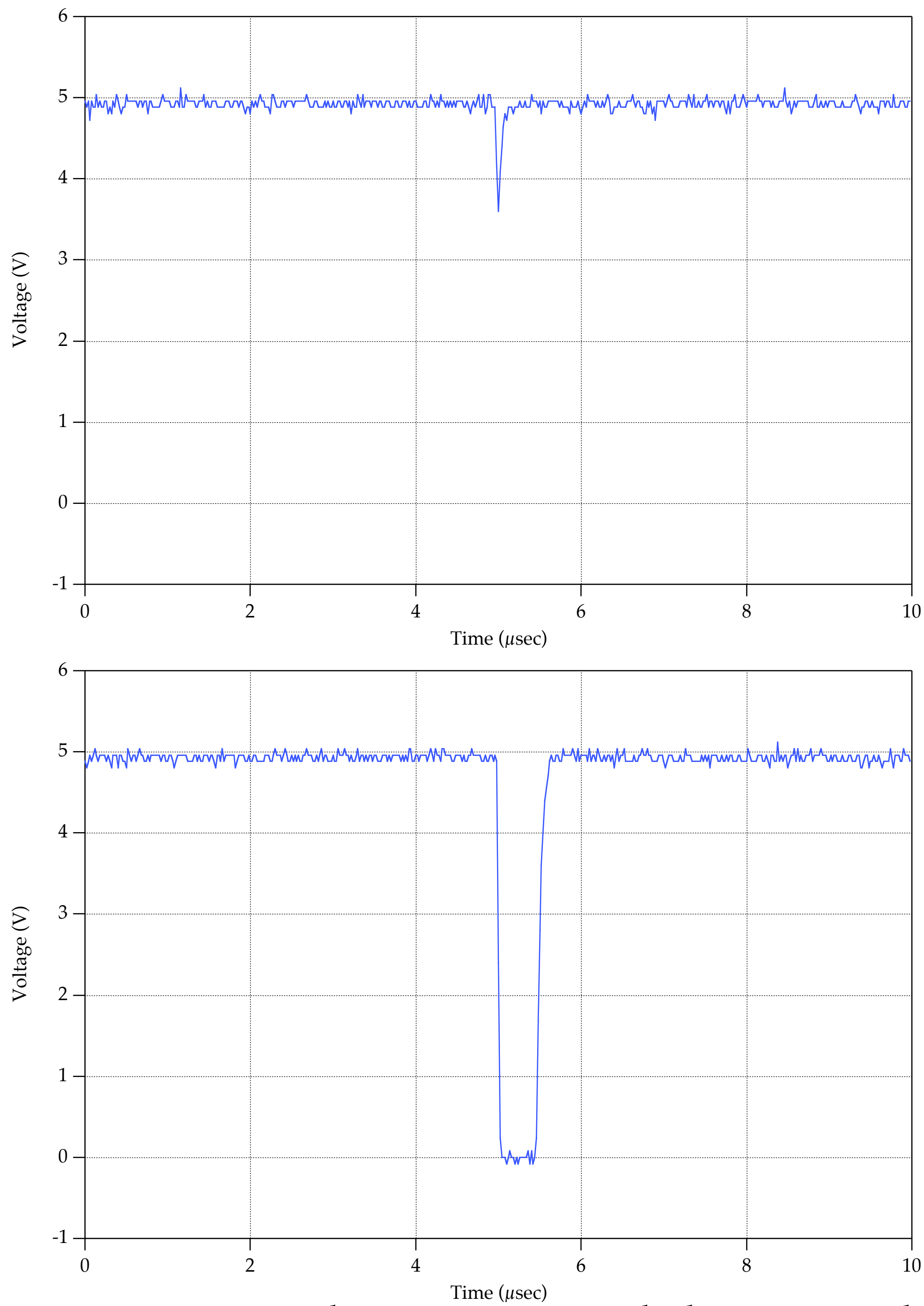


Figure 7. Sample transients for the low effective LET, high output case showing the shortest transient (top) and widest transient (bottom).

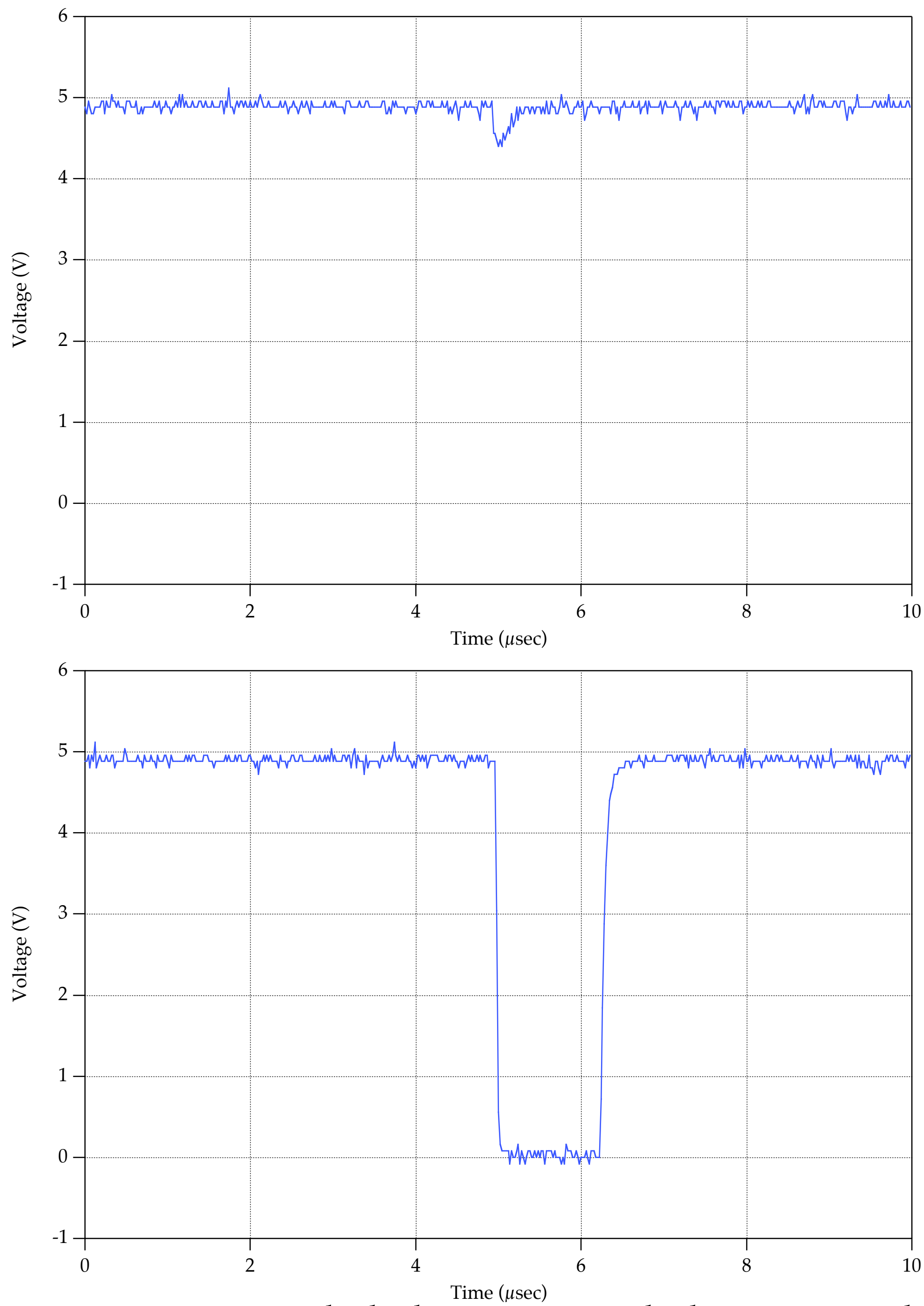


Figure 8. Sample transients for the high effective LET, high output case showing the shortest transient (top) and widest transient (bottom).